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TITLE: LOW-LEVEL-WASTE-DISPOSAL METHODOLOGIES

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LOW LEVEL WASTE DISPOSAL METHODOLOGIES

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1. HISTORY OF LOW LEVEL DISPOSAL

Low level radioactive wastes were first generated in significant quantities during the early 1940's. They consisted of both liquid and solids generated by government weapons development at locations such as Los Alamos, Hanford, and Oak Ridge. Solid wastes were disposed of by burial in shallow pits, to provide both physical control over classified materials, and more radiation protection than would conventional open dumps. Liquid wastes were disposed to seepage pits or absorption beds.[1]

Gradually, liquid waste treatment plants were developed, and the residual sludges were placed in the burial grounds. Seepage pits are no longer in use at these facilities, although there is some tank storage of intermediate level wastes that await solidification.[1]

Wastes were also disposed of by ocean dumping to sites in both the Atlantic and Pacific. Relatively shallow sites were used (1000-2000 m) on the continental shelf.[1]

During the 1950's, a growing volume of wastes from the private sector were disposed of both by ocean dumping and by burial at government burial grounds. However, in 1962, commercial burial sites were opened at Maxey Flats, Kentucky, and at Beatty, Nevada, for receipt of wastes from the private sector, and the Atomic Energy Commission (Now Department of Energy, DOE) discontinued receipt of commercial wastes.[1]

Ocean disposal was curtailed with the opening of these commercial sites and discontinued by 1970, for both environmental and economic reasons. Currently, all low level waste generated in the United States is disposed of by shallow burial. Ocean disposal to deep waters (greater than 4000 m) is used by European countries without adequate land area for disposal.

2. CURRENT PRACTICE

There are currently five major DOE burial sites, and six commercial sites (Fig. 1). Three of the commercial sites (Sheffield, IL; Maxey Flats, KY, and West Valley, NY) are no longer receiving wastes. Additionally, there are a number of small burial operations at both government and non-government facilities.[1]

The characteristics of these sites vary considerably, as a function of both climate and site hydrogeology.[1] The dominant features of these sites are summarized in Table 1 and Table 2.

Wastes received at commercial sites are all packaged to meet Department of Transportation requirements. These include stipulations on package integrity (as a function of radioactivity in the wastes), allowable surface radiation, etc. However, the packaging has not, in general, been designed to aid in containment after burial. At DOE sites, where a burial ground is part of a larger reservation, wastes are frequently not transported on public highways, and packaging requirements are less stringent.

The radionuclide content of major waste types is summarized in Table 3. It should be kept in mind that the term "low level" is to some extent a misomer. Wastes vary in radionuclide content from essentially non-contaminated (as for some dry compressible wastes) to concentrations approaching High Level Waste (such as some reactor resins). In 1970, the

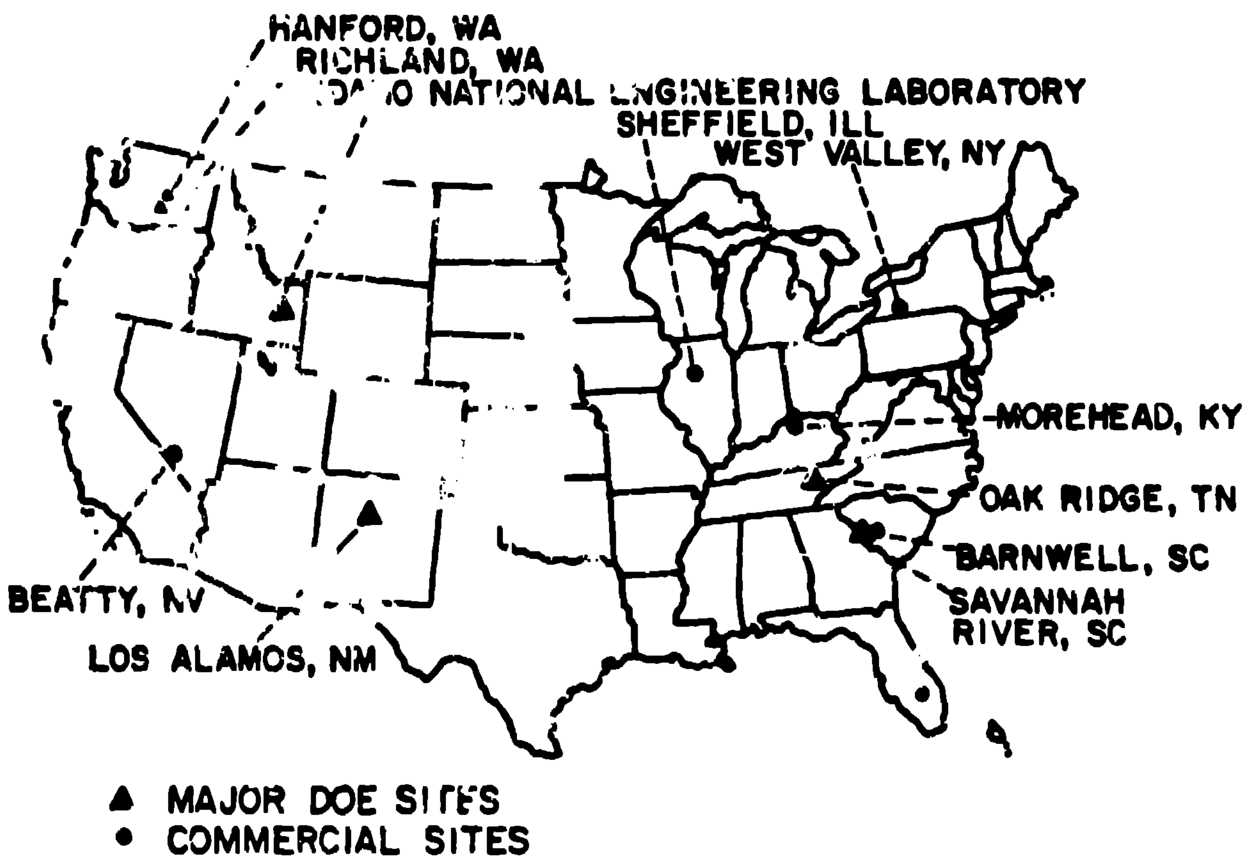

Fig. 2
Location of Disposal Sites

Table 1. Characteristics of commercial burial sites[a]

Characteristic	Burial site: West Valley, N.Y.	Morehead, Ky.	Barnwell, S.C.	Sheffield, Ill.	Beatty, Nev.	Richland, Wash.
Mean annual precipitation (mm)	1000	1200	1100	900	100	200
Surficial material	Glacial drift silty clay/interbedded sand and gravel	Weathered shale; clay and sand	Sand and clay-sand	Glacial drift: sand, silt, and gravel	Alluvial sand and gravel	Clay, sand, and gravel
Thickness (m)	20 to 30	3 to 5	0 to 10	20 to 30	Over 200	Over 150
Interstitial permeability to water (cm/day)[b]	Low (0.5)	Very low (0.02)	Very low (0.02)	Variable (0.04 to 40)	Variable (0.02 to 0.1)	Variable
Bedrock material	Shale	Shale	Clay, sand, and sandstone	Shale, claystone, and coal	Metamorphic and sedimentary	Volcanic
Structure	Flat-lying	Flat-lying	Flat-lying	Flat-lying	Folded	Flat-lying
Groundwater depth to shallowest saturated zone (m)	Variable, 1 to 20	1 to 2	10 to 20	5 to 20	80 to 90	100
Depth of continuous groundwater zone (m)	20	10 to 15	10 to 20	5 to 20	80 to 90	100
Depth to regional aquifer (m)	None present	None present	200	100	80 to 90	100
Surface-water proximity	On site	500 m	At site boundaries	At site boundaries	3 km	10 km
Flow characteristics	Small, perennial	Small, perennial	Small, perennial	Lake to north; small, perennial to south	Ephemeral, after storms	Large, perennial (Columbia River)
Sorptive or ion-exchange capacity of material surrounding burial[b]	High	High	Moderate	Low	Moderate	Moderate
Principal flow paths away from burial	Shale fractures and lenses in drift	Shale fractures	Pore spaces in sand	Pore spaces in till	Unsaturated flow in pores	Unsaturated flow in pores

[a]Data from Ref. 1.

[b]Interstitial permeability and sorptive capacity can be bypassed by flow along fractures or other high-permeability zones.

Table 2. Characteristics of ERDA burial sites[a]

Characteristic	Burial site				
	Savannah River	Oak Ridge	Los Alamos	Idaho	Hanford
Mean annual precipitation (mm)	1100	1300	400	200	200
Surficial material type	Sand and clay-sand	Weathered shale and fill	Weathered tuff	Alluvial sand and gravel	Clay, sand, and gravel
Thickness (m)	0 to 10	0 to 10	0 to 2	1 to 10	Over 150
Interstitial permeability to water[b]	Very low	Very low	Moderate	Moderate	Variable
Bedrock material	Clay, sand, and sandstone	Shale	Volcanic tuff	Basalt	Volcanics
Structure	Flat-lying	Folded	Flat-lying	Flat-lying	Flat-lying
Groundwater depth to shallowest saturated zone (m)	10 to 20	0 to 5	200 to 400	60 to 300	100
Depth of continuous groundwater zone (m)	10 to 20	2 to 5	200 to 400	60 to 300	100
Depth to regional aquifer (m)	200	None present	200 to 400	60 to 300	100
Surface-water proximity	On site	On site	1 km	3 km	10 km
Flow characteristics	Small, perennial	Small, perennial	Small, ephemeral	Small, ephemeral	Large, perennial (Columbia River)
Sorptive or ion-exchange capacity of material surrounding burial[b]	Moderate	High	High	Moderate	Moderate
Principal flow paths away from burial	Pore spaces in sand	Shale fractures and pores in fill	Fractures and pores in sand	Pores in sand	Pores in sand

[a]Data from Ref. 1

[b]Interstitial permeability and sorptive capacity can be bypassed by flow along fractures or other high-permeability zones.

Table 3. Volumes and Activities of Low Level Waste

Source	Annual Volume (m^3)	Concentration Ranges (Ci/m^3)
DOE[a]	6.5×10^4	0.14[b] - 300[c]
Commercial[d]		
Reactors	3.5×10^4	0.16[e] - 200[f]
Institutional	2.1×10^4	0.12[g]
Industrial	2.0×10^4	23[h]

[a] From DOE SWIMS data for 1979.
[b] Average low-level alpha.
[c] Average induced activity.
[d] From Reference 3.
[e] Routine trash,[3]
[f] Irradiated components.[3]
[g] Overall average,[3] includes α, β, and γ.
[h] Overall average - no data on radionuclide composition.[3]

Atomic Energy Commission (now DOE) determined that low level wastes with concentrations of transuranic elements greater than 10 nanocuries per gram would no longer be disposed of by shallow land burials.[4] Similar restrictions are now in effect at commercial sites. However, low level wastes still contain transuranic elements at concentrations below this limit, as well as other long-lived radionuclides suche as radium, technicium, iodine, etc. Transuranic Wastes may be disposed of by means similar to that for High Level Wastes.

While there are some site-to-site variations, burial practices at both DOE and commercial facilities are similar. Trenches are excavated 10-20 m deep, and filled with wastes to within 1 or 2 m of the surface. Excavated material is used for backfilling around the waste material, and for a final cover over the wastes. This overburden provides radiation shielding for waste with high gamma activity, prevents significant contact between the wastes and plants or animals, is compacted to minimize water infiltration, and profides a buffer against exposure by erosion. The location and operation of the site is designed to restrict the amount of water moving through the waste material so as to encourage containment of radionuclides within the site boundaries.

Shallow burial of low level waste is a continuously evolving practice, and each site has developed its own solutions to the handling and disposal of unusual waste forms. Further, there are no existing national standards for such disposal, although the DOE Nuclear Regulatory Commission (NRC), and Environmental Protection Agency are in the process of developing such.

In this context, it is more informative to discuss specific problems that have arisen at existing sites, than to provide detailed descriptions of disposal practices at each site. These problems have led to improvements in shallow burial practices, and to increased attention to alternative disposal methodologies, such as mined cavity disposal.

3. SITE PERFORMANCE

There have been no radionuclide releases from shallow burial sites that pose a threat to public health or safety.[5] However, releases have occurred at nearly every site. While it was originally expected that sites would provide complete containment, it is now recognized that zero release is not a practical goal.[6] However, the releases at existing sites provide insight into what burial site conditions and practices favor containment.

The performance record of existing sites is summarized in Table 4. The sites have been categorized according to a combination of climatic and subsurface conditions.

- Arid Sites
  The sites at Los Alamos, NM, Idaho, Handord, WA, Beatty, NV, and Richland, WA have annual precipitation less than 400 mm per year. Evaporation rates are high, and very little moisture infiltrates into the waste. Thus, saturated conditions rarely if ever exist in the burial trenches. The depth to groundwater exceeds 30 m, and may be as much as 200 m. Radionuclide transport is thus dominated by partially saturated flow, at rates much slower than for saturated groundwater transport. There may be significant vapor phase movement of moisture and volatile radionuclides. Radionuclide transport is quantitatively small, but difficult to monitor precisely. Release of radionuclides from these sites (Table 3) results from intrusion of the biosphere into the waste, including both plants and animals, and from releases during site operations before the waste is buried.

- Humid Sites with moderate soil permeability.
  The sites at Barnwell and Savannah River are adjacent, located in relatively permeable Gulf Coastal Plain sediments. Although precipitation is high, and evaporation low, the sites have good subsurface drainage, and the shallowest water table is at a depth of 15-25 m.

Table 4. Performance Record of Burial Sites

Site & Classification	Radionuclide Releases Tritium	Radionuclide Releases Other	Probable Cause of Release	Extent of Release
Arid				
Beatty, Nevada	No	No		
Hanford, Washington	No	Yes	Plant Uptake	Near Trench
INEL, Idaho	No	No	...	...
Los Alamos, New Mexico	Yes	No	...	Near Trench
Richland, Washington	No	No	...	...
Humid, Poorly Drained				
Maxey Flats, Kentucky	Yes	Yes	Water Accumulation in Closed Trenches and Effluents from Liquid Treatment	Offsite
ORNL, Tennessee	Yes	Yes	Shallow Water Table	Offsite
Sheffield, Illinois	Yes	Yes	Parched Water in sand lenses	Onsite
West Valley, New York	Yes	Yes	Water Accumulation in Closed Trenches and Effluents from Liquid Treatment	Offsite
Humid, Well Drained				
Barnwell, South Carolina	No	No	...	...
SRP, South Carolina	Yes	No	Near Surface Ground Water	Onsite

- Investigations at Savannah River show that while the shallow groundwater aquifer underlying the site receives some radionuclides from the burial grounds, it is not a water supply source, and off-site contamination is well within currently acceptable levels.[5] The geologic formations at the site are sufficiently uniform to allow modeling of the partially saturated and groundwater flow systems. Thus, prediction of radionuclide migration rates and directions is reliable. Similar investigations are ongoing at the Barnwell commercial site.

- Humid Sites with low soil permeability
  The burial sites at Maxey Flats, KY, Sheffield, IL, West Valley, NY, and Oak Ridge, TN, all have high precipitation and low evaporation. Additionally, the burial material is relatively impermeable, being shale or glacial still. These sites were chosen with the expectation that water flow rates through the subsurface would be slow, resulting in effective containment of the radionuclides.

  However, because of the low permeability and high precipitation saturated or near saturated conditions occur close to the surface, often within the burial trenches. The permeability of the burial medium is commonly less than that of the trench caps, leading to water accumulation in the trenches (Table 2). Surface overflow may result (such as at West Valley) or high hydraulic heads may produce lateral flow in fractures or sand lenses. Further, flow is preferentially through high permeability zones, rather than being uniformly distributed through the material. Thus, radionuclide migration is difficult to monitor and when observed is difficult to intrepret.

It must be emphasized that none of the releases from existing sites poses a threat to public health or safety.[5] Rather the concern over these releases derives from uncertaintly regarding their exact extent, and the prognosis for the future. The natural system, including the hydrology, plant and animal community, and human activity is difficult to describe precisely. The waste material is heterogeneous, chemically, physically and radiologically. Chemical reactions within the trenches and within the surrounding burial media are difficult or impossible to describe.

A second class of concerns relate to future conditions at the site. There is no general agreement as to how long these sites must be controlled, either to prevent human contact with the waste or to provide continued site maintainance. While theoretical analyses have been performed to evaluate the result of possible human activity at the site[8] the conclusions are based on numerous assumptions about the waste and the exposure mode. Long term changes in natural processes, such as precipitation, are also difficult or impossible to evaluate.

4. PROPOSED SOLUTIONS

Improvements in the methodology for low level waste disposal are occurring on several fronts. Standardized criteria are being developed by both the NRC and by DOE. Improved techniques for shallow burial are evolving at both commercial and DOE facilities, as well as through research sponsored by NRC, DOE, and the Environmental Protection Agency. Alternatives to shallow burial, such as deeper burial or the use of mined cavities is also being investigated by DOE.[7]

Criteria Development

A continuing concern regarding low level waste disposal has been the lack of any standardized criteria for site selection and operation. Both the NRC and DOE are currently developing such criteria.

A current rulemaking effort within NRC involves proposing a new 10 CFR Part 61 (Ref. 6) and amendment of 10 CFR Part 20 (Ref. 9). The new regulations will set out performance objectives for land disposal of radioactive waste. The objectives will provide for protection of the general population from releases of radioactivity, protection of individuals from inadvertent intrusion, protection of individuals during operations, and stability of the site after closure. The rule will establish technical requirements for siting, design, operations, and closure activities for near-surface disposal facility. It will establish requirements for waste classification, financial assurance, and institutional controls applicable to all types of land disposal. Licensing procedures covering all phases of the life of the sites will be provided. Provisions for consultation and participation by State government and Indian tribes will also be provided. The amendments to 10 CFR Part 20 will establish detailed transfer requirements and a manifest tracking system for wastes. The proposed rules should provide a regulatory base for licensing new sites for the disposal of most of the nation's commercially generated low level waste and guidance to Agreement States as they develop compatible regulations.

The Low Level Waste Management Program within DOE is also developing standardized criteria for all phases of low level waste management, including waste form and container specifications, site selection procedures, and operational criteria. These will be produced in a handbook format, for use by state or federal agencies responsible for locating or operating future disposal sites.

Improved Methods

Extensive research programs are underway within the NRC, DOE, and the US Geological Survey, to develop improved knowledge of existing sites, and apply better engineering to burial site design and operation. Experiments at Los Alamos, Oak Ridge, and Savannah River will produce improvements in cap designs and water control techniques. DOE and NRC are sponsoring work on waste treatment methodologies to produce more stable, less leachable waste materials.

Alternatives

While shallow burial may be suitable for much of currently generated low level waste, criteria now under development will identify some concentration level for certain radionuclides that is not suitable for shallow burial. The ban on shallow burial of Transuranic Waste has been in effect for about ten years at DOE sites. Similar bans were imposed during the 1970's at commercial sites. Restrictions on other radionuclides are anticipated within both DOE and NRC criteria now under development. The wastes restricted from shallow burial will have to be disposed of by some alternative technology.

Improved protection from surface related release processes such as erosion, human or animal intrusion, etc. can be obtained by placing the waste deeper in the ground. Cover thicknesses of 10 or more meters have been proposed, although 5 meters of cover may be sufficient.[10] Deliberate excavation of the waste by "treasure hunters" or archaeologists of the future may still occur, but deeper burial will prevent most inadvertant intrusion into the waste. The deeper burial concept, however, may require burial within saturated material in some humid locations. Such disposals are under considerations in Canada.[11]

Disposal into cavities mined specifically for waste disposal can provide nearly positive protection against all but the most determined intrusion. Additionally, sites can be selected that are essentially isolated from the hydrosphere, generally eliminating radionuclide migration. The technical difficulties of developing mined cavities are more site-specific than generic.

Engineered storage may be used for decay storage of relatively short-lived waste or as an interim measure before decommissioning of a waste source (such as a reactor). Site surveillance and control will be required throughout the hazardous lifetime of the wastes to prevent environmental and human intrusion.

Ocean disposal of low level waste is currently practiced by many countries, using deep (4000 m) dump sites in the Atlantic and Pacific Oceans. (The United States has not used ocean dumping since 1970.) Placement of waste in the sediments within the deep ocean basins (sub-seabed disposal) is being investigated by the United States high level waste disposal program. Either option appears to provide more than adequate protection for current low level waste, but may evoke considerable social and political discussion.

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